THE ANEROID BAROMETER, ITS THEORY AND ITS USE, WITH SPECIAL REFERENCE TO THE DETERMINATION OF ALTITUDES.

BY

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THE ANEROID BAROMETER, ITS VARIOUS FORMS, ITS THEORY AND ITS USE, WITH SPECIAL REFERENCE TO THE DETERMINATION OF ALTITUDES.

By E. A. GIESELER, C.E.

I. GENERAL DISCUSSION.

The motor of all aneroids consists in an hermetically sealed box, the air of which has been exhausted as completely as practicable, and the flexible sides of which will consequently perform certain motions, when the pressure of the atmosphere changes. These motions are, however, too small to be perceived by the unaided eye, and they are, therefore, transmitted to a suitable mechanism, by means of which they are magnified to such an extent that they can be discerned and measured.

The invention of the aneroid dates back to the beginning of this century, one of the oldest forms being the one con-

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structed by Bourdon, in which the box has the shape of a tube sealed at both ends, and bent into the shape of a circle. A small open space remains between the two ends, and diametrically opposite this gap the tube is fastened to a supporting plate. The cross-section of this tube is either rectangular or oval, and the direction of its greatest height or diameter stands at right angles to the plane of the circle into which the tube has been bent, which is parallel to the supporting plate.

When compressed air or steam is admitted into such a tube, the inner pressure thus created will have the tendency to straighten it, on account of the excess of pressure exercised on the *greater* area of the *outer* circular side as compared with the *smaller* area of the *inner* circular side. Any increase of the inner pressure will result in a further flattening of the circle into which the tube has been bent, while a decrease of it will cause such curve to be sharpened.

Precisely the reverse will take place, when the tube has been exhausted, because then the acting force, instead of being an *inside* pressure, will be the *outside* pressure of the atmosphere. The tube being held as described before at one point only, which is situated diametrically opposite the opening between the two ends, it is evident that the changes of form of the curve must result in movements of these ends; under the influence of high atmospheric pressure they will approach each other, while a decrease of pressure will widen the gap between them. The movements of the ends are transmitted by a simple arrangement to a hand pointing on a graduated dial. They are magnified either by levers acting on the *short* arm of the hand or pointer, or, when the latter is mounted centrally, by means of a toothed wheel and pinion.

This form of the aneroid has nowadays been entirely superseded by others, in which the vacuum box has the shape of a flat cylinder, into the upper and lower circular ends of which concentric grooves are pressed in order to equalize the motions performed by them under the influence of the varying atmospheric pressure. To the side of the vacuum box is soldered a small tin pipe, through which the

air is exhausted. After this has been done the pipe is sealed and the upper and lower ends of the box are now deflected towards its interior by the pressure of the atmosphere, the amount of such deflections for a given pressure being dependent on the strength of the plates. This must be sufficient to prevent too great a departure from the horizontal positions, in order not to strain the plates beyond their limit of elasticity. The movements are, therefore, necessarily small; a fall of $\frac{1}{100}$ of an inch in the mercurial barometer corresponding to an approach of about $\frac{1}{20000}$ of an inch of the plates of the vacuum chamber.

II. THE NAUDET ANEROID.

To measure such exceedingly small quantities, one class of modern aneroids is provided with an ingenious mechanism invented by Vidi and later improved by Naudet, the main parts of which are shown in *Fig. 1*.

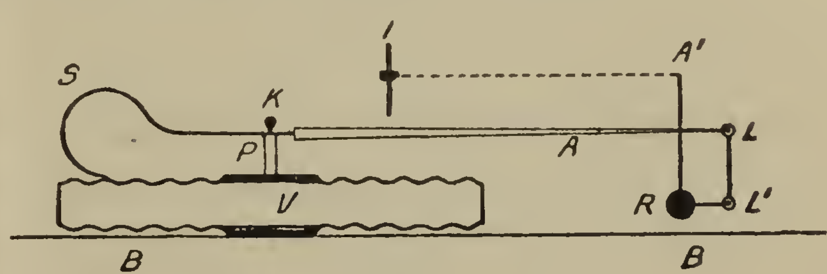

FIG. 1.

To the base or foundation plate *B B* are firmly attached a laminated spring *S* and the vacuum chamber *V*. The latter carries upon its centre an upright pillar *P*, which passes through an opening in the spring and presses on its upper side by means of the knife edge *K*. An elastic system is in this way formed by vacuum chamber and spring and the pulsations of the former will be imparted to the latter. The horizontal arm *A* is firmly attached to the spring and will therefore follow its movements. These will appear in a magnified scale at the end *L* and are transmitted by the two links *L* and *L'* to the rocker shaft *R*, which turns in bearings attached to the base plate, but not shown in the diagram. The turning motions of *R* are further magnified by the arm *A'* and thence transmitted by a small chain *C* to the central shaft *I*, which carries the index pointer. The required tension on the chain is produced by a spiral spring acting on

the central shaft. This spring and the bearings for the central shaft are not shown in the diagram.

The graduation of the dial on which moves the index pointer, like the hand on a watch dial, is made to correspond as nearly as possible with the reading of the mercurial barometer, and, like the latter, is expressed in millimetres or in inches. Perfect accuracy in this respect cannot be attained; there will always be required a certain correction for graduation. This and the corrections for temperature are the most important ones for practical work and will be discussed further below.

As apparent from the above, the use of the Naudet aneroid is very simple; in fact, the handling and reading of no instrument could be simpler. But this advantage is obtained by means which, in themselves, constitute the source of undoubted defects. The magnification and the measuring of the small movements of the vacuum chamber are performed by means of an exceedingly delicate mechanism, which is liable to get out of order unless great care is exercised in handling and transporting the instrument. Such constant and unremitting care, however, cannot be exercised under all circumstances, especially not in our country where the aneroid, in the hands of the railroad engineer for instance, is frequently subjected to swift transportation on horseback over many miles of rough country, the jolting and jarring of which are almost certain to prove injurious to the instrument. Even ordinary transportation in good packing frequently puts a Naudet out of working order, and no dealer in these instruments can warrant their safe arrival at the end of a long railroad journey.

Hence the frequent complaints of engineers, who have bought instruments in New York or some other great centre and to their dismay find them giving out completely when needed, a calamity which will be all the more annoying, when it happens, as it naturally often does, at a place far removed from any facilities for repairing.

Aside from such heavy shocks, which may at once render a Naudet perfectly useless, an instrument actually used in the field is necessarily exposed to small shocks, which even

the most careful and experienced observer cannot entirely avoid, and the continuance of which tends to produce a slackening of the mechanism. The gradual deteriorating from this cause of Naudet aneroids, during their use in the field, is a well-established fact, even when they are in the hands of the best observers (Report of Mr. J. Campbell, R. N., published in *U. S. Monthly Weather Review*, September 1879).

Finally a very important defect should be mentioned here, which may not inadequately be termed the "elastic reaction" of the instrument and which asserts itself in the tardiness with which the mechanism accommodates itself to changes in atmospheric pressure.

C. Kroeber, in his experiments with Naudet aneroids (*Zeitschrift für Vermessungswesen*, Heft. 8, 1881), has found that it took the instrument about two days to accommodate itself to a change of pressure corresponding to five inches of the mercurial column, the readings taken immediately after the pressure had been changed differing nearly two-tenths of an inch from the final ones. If not considered in the case of a measurement of altitudes this difference would have constituted an error of about 200 feet in about 5,000 feet.

It is true that the quality of "elastic reaction" in a measure is common to all aneroids, but it is especially pronounced in the Naudet, on account of its peculiar and com plicated mechanism. As apparent from the above, the latter circumstance constitutes the origin of several serious defects, the only remedy for which, evidently consists in a simplification of the mechanism.

But it is as evident that such a simplification could not be attained, without at the same time sacrificing in a measure the ease and simplicity of handling and reading the instrument. Some of the work, which in the Naudet aneroid is performed by the complicated mechanism itself, in an instrument of simpler construction necessarily had to devolve on the observer. The difficulty then, consisted in harmonizing, in the most advantageous manner possible, requirements, the fulfilment of one of which impaired the fulfilment of the other.

III. THE GOLDSCHMID ANEROID.

This problem was solved after years of experiments by J. Goldschmid, of Zurich, about 1860, through an entirely novel construction, in which the movements of the vacuum chamber are measured by a micrometer screw acting on a peculiar lever arrangement, combined with optical magnification. In the following diagram, the left-hand side of which represents a section through the instrument, the exceedingly simple arrangement of the working parts is clearly shown.

To the centre of the top of the vacuum chamber *A A* is soldered a crank-shaped piece, which ends at one extremity in an upward turned knife edge; the latter supports the main lever *e e''*, which in its turn swings freely around the fulcrum *e''*. The movements of the vacuum chamber are

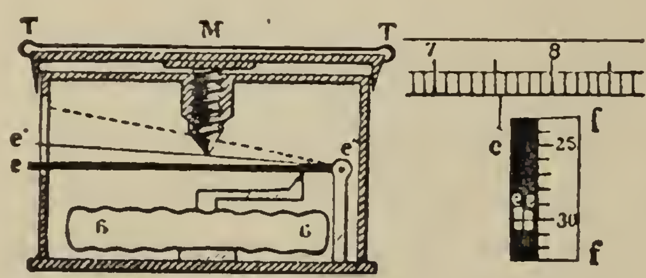

FIG. 2.

transmitted by the supporting knife edge to the main lever, the end *e* of which carries a small hammer-shaped piece. On the face of this is marked a horizontal index line, which will move vertically up and down, according to the varying pressure of the atmosphere. These movements take place alongside of a vertical ivory scale, which serves to measure them and which bears a graduation corresponding to the full inches of the mercurial column (see the right-hand side of *Fig. 2*, which shows the hammer and scale in front view).

While from the ivory scale the full inches only of the aneroid reading can be taken, the following arrangement serves for measuring the tenths and hundredths of inches. A fine and light spring *e' e''* is soldered to the main lever near the end *e''*; at the other end *e'* it carries a small hammer, similar to the one described before; when no pressure is exercised on the spring this hammer is held by the elas-

ticity of the same a little above the top of the hammer e, standing at the same time sideways of it.

To the cover *T T*, of the brass case enclosing the entire apparatus, is attached the micrometer screw *M*, which can therefore be screwed up or down by turning such cover. The lower pointed end of the micrometer acts on the spring $e' e''$, and when a reading is to be taken it is screwed down until the spring has been depressed so much that the index line of e' coincides with the index line of e.

It is at once clear that this position of the two hammers, which is shown in the diagram, corresponds to a certain distance between the point of the micrometer screw and the main lever, a distance which remains the same for all the various positions into which the main lever may be raised or lowered by the movements of the vacuum box. The point up to which the micrometer screw has to be screwed down, in order to make the two index lines coincide, is thus made a measure of the position in altitude of the main lever. This measure is read by means of a graduation engraved on the circumference of the cover and dividing the same into 100 equal parts, each of which corresponds to one hundredth of an inch of mercurial barometer height. The graduation is so wide that thousandths can easily be estimated.

The *modus operandi* then, in using the Goldschmid aneroid, is as follows:

The outer morocco case of the instrument is opened, and holding the latter in a horizontal position the cover is screwed down, while at the same time the two little hammers, protruding from the brass case through a window-like opening, are observed by means of the attached microscope. When the upper hammer is seen to commence moving downward, then the micrometer screw should be turned carefully and slowly, and when the two index lines coincide it is stopped entirely. Before such coincidence is obtained the instrument should be tapped lightly on the top, in order to eliminate any inertia of the mechanism. It is very important that this tapping should always be done in the same position of the hammers, because if, for instance, it is

done sometimes before coincidence and at other times at coincidence, then differences in the readings will be the consequence, that may amount to as much as $\frac{1}{100}$ of an inch. In order to insure uniformity in this respect it is advisable to make it a standing rule, *to tap when the lower edge of the upper hammer arrives at coincidence with the index line;* thence forward the screw should be turned very carefully, avoiding all further shocks.

IV. DISCUSSION OF THE CORRECTIONS.

In order to find, from the reading obtained by a Naudet or a Goldschmid aneroid, the height of the mercurial column of 32° Fahrenheit temperature, corresponding to the same pressure, three corrections are required, viz: for temperature, for graduation and for position, the latter not being required when the instrument is used for measuring altitudes only.

Let A represent the reading of the aneroid, T the temperature of the instrument in degrees Fahrenheit, and A_0 the reading that would have been obtained if the temperature had been 32° Fahrenheit, then we have, concerning the correction for temperature:

$$A_0 = A + \alpha\, F(t) \tag{1}$$

wherein α is the coefficient for temperature, the structure of the function t for the present remaining undecided.

Regarding the correction for graduation, aneroids are generally set so, that at a reading of thirty inches there is coincidence between them and the mercurial barometer, after the correction for temperature has been made on both. The coefficient of graduation is the difference between one inch of the mercurial column and one inch of the aneroid graduation: this—multiplied by the difference, thirty—reading, clearly renders the correction for graduation. Hence we have

$$B_0 = A_0 + \beta\,(30 - A_0)$$

wherein B_0 the height of the mercurial column reduced to the freezing point and β the coefficient for graduation.

The above described coincidence between the aneroid and the mercurial at thirty inches, even if completely attained, rarely lasts long, and in order to compensate for this a constant must be added to the right-hand side of the above equation. This constant is the correction for position and is generally designated by the letter C; we therefore have finally

$$B_0 = A_0 + \beta\,(30 - A_0) + C \qquad (2)$$

Proceeding now to discuss the structure of the above function of t, equation (1), it should be remembered that each change in temperature causes two different forces to act on the mechanism. In the first place, the corrugated surface of the vacuum chamber having a greater area than corresponds to its circumference, is expanded too much by a rise in temperature, and this excess of expansion causes a *depression* of the surface. The reason why the latter is not *raised* instead of being *depressed* is to be found in the circumstance, that in all good instruments it is bent slightly towards the interior, so that, even under a minimum of atmospherical pressure, it will only rise about to the horizontal, but never bulge outward beyond this.

The second force is created by the small quantity of air, present in all so-called vacuum chambers, being expanded by the additional heat imparted to it, thus exercising an inside pressure, that tends to counteract the first described force.

In the Naudet aneroid the chamber is exhausted as much as possible, and the inside pressure caused by a rise of temperature under all ordinary circumstances is therefore much smaller than the force caused by surface expansion of the box and pressing such surface towards the interior. These instruments will therefore be affected by a rise of temperature in the same way as by an increase of atmospherical pressure, that is, the reading of the instrument will become higher. Hence the correction for temperature in Naudet aneroids is subtractive for all temperatures above the freezing point and additive for all temperatures below.

From what has been said, it is clear that the second or inside force can be increased by admitting additional air

into the vacuum chamber, and it was suggested by Professor Kohlrausch, that in this way the two forces might be made to counterbalance each other entirely, thus reducing the correction for temperature to nothing. The impossibility of this was demonstrated by Professor Weilenmann, whose extensive theoretical and experimental researches on this subject rendered the following results:

(1) When the temperatures are plotted as ordinates and the corrections pertaining to them as abscisses, then a parabola is obtained.

(2) The apex of this parabola can be shifted to lower or higher temperatures, by respectively increasing or diminishing the amount of air contained in the chamber.

Although these principles differ theoretically from Bauernfeind's opinion, that the correction for temperature increases in direct proportion to the temperature, yet for Naudet aneroids, with highly exhausted chambers, there is no great practical difference between both assertions. This will be seen clearly from the following diagram, in the left-hand part of which a correction curve for temperature is shown, that was obtained by Professor Weilenmann from actual tests with an aneroid, the chamber of which was exhausted as completely as possible. For all such temperatures as are likely to occur in practical work, this curve does not depart materially from a straight line, which latter would be the expression of Bauernfeind's law in the diagram.

TEMPERATURE IN DEGREES CELSIUS.

Professor Weilenmann's above named principles have been utilized in the construction of the Goldschmid aneroid for the purpose of reducing as much as possible the correction for temperature. An amount of air corresponding to a few inches of the mercurial column is admitted into the vaccuum chamber, thereby shifting the apex of the parabola to near the freezing point and consequently reducing to practically nothing the corrections in that vicinity. An example of this is given in the right-hand part of *Fig. 3*, where a correction curve is shown for a vacuum box, which contained an amount of air corresponding to six inches

of the mercurial column. The characteristic differences between this curve and the high vacuum curve in the left-hand part of the same diagram, are at once apparent and strikingly to the advantage of the former. Under the influence of high temperatures the inner pressure now exceeds the force, bending the surface towards the interior, in other words, such influence will act on the Goldschmid aneroid like a *decrease* of atmospheric pressure.

Summing up, we find that the correction for temperature for the Goldschmid instruments in the vicinity of the freezing point is practically nothing, again, that as a general rule it is everywhere considerably less than for the Naudet aneroid or for the mercurial barometer, and, finally, that what little there is of it, is *additive*.

While the Goldschmid aneroid is not claimed to be entirely compensated for temperature, the corrections for the latter are doubtless in it reduced to very small quantities, a table of which, resulting from careful tests made by the manufacturer, accompanies every instrument.

For some of the Naudets in the market, entire compensation is claimed, but if the practical test is made, probably one out of ten will be actually found so, while the corrections of most of the rest will exceed those of the Goldschmid, without the purchaser being furnished with a table for them.

A simple and very effective method of ascertaining the correction for temperature consists in the use of warm, tepid and cold water baths, and finally the ice bath. By their means the inner temperature of an instrument can be varied from the freezing point upward, to say 100° or more. The observations must of course be made together with observations on a mercurial, and both are recorded in about the following way:

Mercurial Thermometer.	Aneroid.			
B_0	A	t	A'	$29{\cdot}094 - A'$
1	2	3	4	5
29·149	29·073	67·0	29·016	0·078
29·148	29·070	66·2	29·014	0·080
29·143	29·073	75·0	29·022	0·072
29·132	29·074	74·4	29·035	0·059
etc.	etc.	etc.	etc.	etc.

In this table the letters at the heads of the various columns have the following meaning:

(1) B_0 is the reading of the mercurial barometer in inches and decimals, as reduced to the freezing point.

(2) A is the reading of the aneroid under the same pressure.

(3) t is the inner temperature of the aneroid in degrees Fahrenheit and decimals.

(4) A' is what the aneroid would have read, if the pressure during the entire series of observations had constantly remained at $B'_0 = 29{\cdot}094$ (this being the average of all the B_0 of the entire series).

The value of A' is found in the following manner: In the case of the actual example cited here a preliminary determination had been made, showing that 1·000 inch of the aneroid corresponded to 0·970 inch of the mercurial column. If, therefore, in the case of the first observation for instance, the mercurial barometer had read 29·094 (instead of 29·149), that is 0·055 less than it actually did read, then the aneroid would clearly have read $\frac{100}{97} \times 0{\cdot}055 = 0{\cdot}057$ less than it actually did read, that is to say $29{\cdot}073 - 0{\cdot}057 = 29{\cdot}016$. The difference between the value $29{\cdot}094 - A'$ as found for the freezing point and as found for any other temperature renders the correction for such temperature. These differences should be found for the various temperatures from the freezing point upward to say 100° F., and then plotted, as shown in *Fig. 3;* from the curve thus obtained a table of corrections is easily deduced.

The correction for graduation has been assumed in equation (2) to stand in direct proportion to the difference 30.—Reading, an assumption, which although not strictly correct is sufficiently so for most practical purposes.

Each Goldschmid aneroid being furnished with a table of corrections for graduations, as well as for temperature, the owner of one of these instruments is saved the trouble of investigations in this respect.

For Naudet aneroids these tables have to be obtained by the purchaser, through direct comparison of the aneroid with the mercurial barometer, the readings of both being reduced to the freezing point by means of the previously

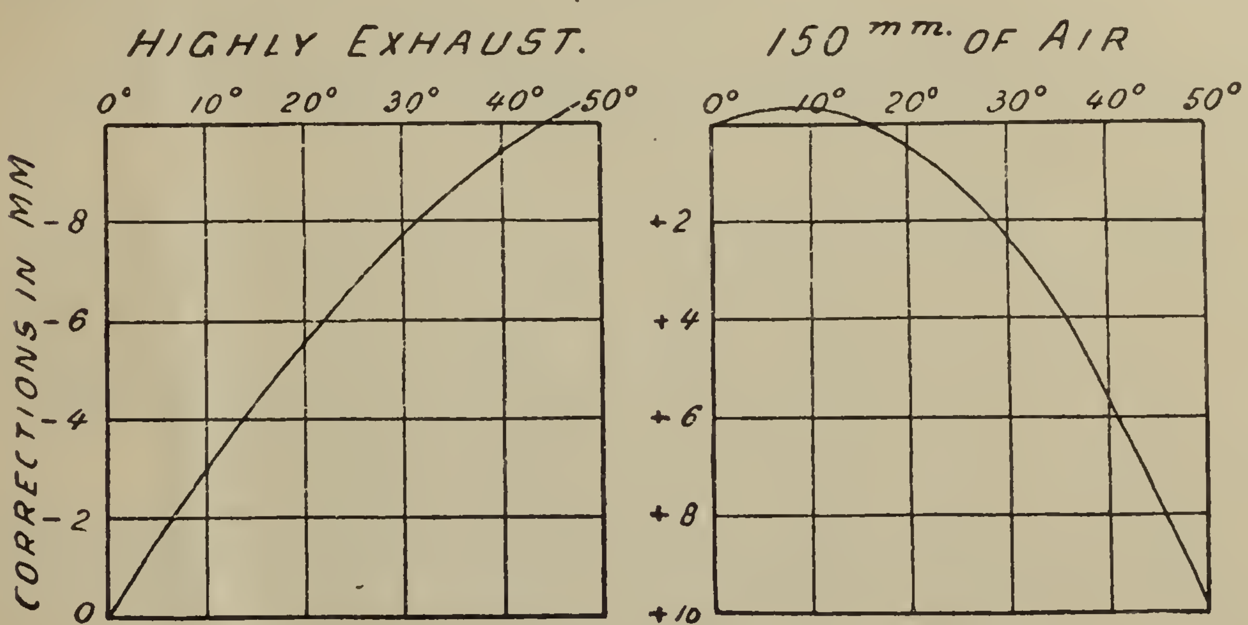

FIG. 3.

determined correction for temperature. The observations are recorded in tabulated form as follows:

B_0	A	t	A_0	A_0-B_0
29·970	29·960	72	30·000	0·030
29·420	29·450	76	29·500	0·080
28·870	28·940	78	29·000	0·130

wherein the various letters have the same meaning as in equations (1) and (2). From the table it is seen that in this case the constant correction for position was

$$C = -0{\cdot}03$$

and that 1·000 inch of the aneroid correspond to 1·100 inch

of the mercurial; the coefficient of graduation therefore was

$$\beta = -0{\cdot}100$$

and by means of these figures a table of corrections for graduation can easily be worked out according to equation (2).

But if it is desired to use the aneroid at great altitudes, then it would not be safe to assume the coefficient β to remain constantly the same, and the investigation should in this case be extended to lower pressures, either by making comparisons between the mercurial barometer and the aneroid at various altitudes, or by making them by means of the air-pump. If the latter method, however, is selected, then a certain correction of the results will have to be made, the nature of which is explained by Dr. C. Koppe as follows:

Suppose an aneroid and a mercurial barometer to be at the same locality and subjected to the same atmospheric pressure, and again suppose a sudden decrease of the force of gravity to take place there. What influence would such an event have on the reading of the two instruments?

Manifestly the reading of the mercurial barometer would not be affected in the least, the weight of the column of air being diminished in the same ratio as that of the mercurial column.

It would be quite different, however, with the aneroid. While the weight of the column of air has diminished, the elastic force of the vacuum chamber has remained the same; the instrument will therefore record a lower pressure.

Consequently, if a journey is undertaken with an aneroid and a mercurial barometer, which read precisely alike, then the coincidence between both will only last as long as the force of gravity remains unchanged. But this force is different in different latitudes, and at different altitudes, and from the latter circumstance results the necessity of a correction of such tables for graduation, that were obtained by means of the air-pump.

It is clear from the above that a reading of twenty-four inches of the mercurial barometer, taken at the level of the

sea under an air-pump, indicates a *greater* actual pressure of air than the same reading taken at an altitude of 7,000 feet above the level of the sea. Hence, a correction has to be *added* to the reading of the aneroid at 7,000 feet altitude, in order to obtain coincidence of such reading with the mercurial barometer. The amount of this correction has been computed by Professor Weilenmann as follows:

Reading (inches), .	31·5	28·0	24·0	20·0	16·0
Correction, ...	0	+ 0·105	+ 0·189	+ 0·270	+ 0·312

The arithmetical sums of these figures and the corresponding corrections found by means of the air-pump are the final corrections for graduation.

The difficulty caused by "elastic reaction," which was mentioned in the beginning of this article is, of course, present also in the Goldschmid aneroid, and the above investigations, as well as all measurements of altitudes, should be carried on with due regard to it. The instrument must be given time in order to fully accommodate itself to any sudden changes of pressure.

But while Kroeber found that the Naudet required days for this, he found the Goldschmid practically accommodated after one or two hours. Again, he found the extreme differences resulting from elastic reaction in the latter instrument only about one-fourth of those in the former. Both these advantages of the Goldschmid, as compared with the Naudet, are doubtless due to the extreme simplicity of the former's mechanism, and in view of them it may be safely asserted that the gradual changes of pressure, taking place during ordinary explorations of mountainous country, will not produce any appreciable errors of elastic reaction in the Goldschmid aneroid.

V. THE DETERMINATION OF DIFFERENCES OF ALTITUDE BY MEANS OF THE ANEROID BAROMETER.

The measuring of altitudes by means of the barometer, is mainly based on two suppositions, viz: Firstly, that the atmospheric strata of equal pressure are horizontal, and secondly, that the temperature of a vertical column of air is

equal to the arithmetical mean of the temperature observed at its top and at its bottom.

These two conditions are probably *never* fulfilled completely in nature, but they are *always* fulfilled more or less approximately. On the greater or smaller deviation from them of the actually existing conditions, depends the exactitude of the result in each case, leaving out the consideration, of course, of avoidable errors of observations.

In accordance with the two principles mentioned, the process of barometric measurement may be described thus: By means of the barometer, be it a mercurial or be it an aneroid, the *weight* of a column of air is determined, and from the *observed temperature* of such column its length is found.

During observations for altitude, therefore, the temperature of the *air* as well as that of the *instrument* must be observed; the first one for the purpose named just now, the last one for the purpose of taking into proper account the corrections for temperature, by reducing both observations to uniform temperature. Besides this, the observations made at the upper and at the lower stations must of course be corrected to graduation, so that thus their difference is made equal as nearly as possible to the difference that would have been obtained by using a mercurial barometer.

It is clear at once that the observations at the upper and lower stations should be made simultaneously in order to obtain both as nearly as possible under the same atmospheric conditions. Observations made by one observer, in passing from point to point with his instrument, are quite unreliable, unless he returns to the previous point after each observation in order to take a second reading there, and thus to find the changes that have taken place in pressure and temperature. Only by means of this tedious and time-robbing procedure, can anything like fair results be obtained by one observer.

For serious work then, two observers, and at least two instruments are required, and the readings of the latter, as well as the outer and inner temperature, should be recorded with great exactitude, so as to be enabled to subsequently

introduce the proper corrections, without which the results are worthless. Great care also should be taken not to expose the aneroid to the direct rays of the sun when taking an observation, but to let it assume as nearly as possible the temperature of the surrounding air in the shadow.

The *modus operandi* in determining differences of altitude may be described about as follows:

A stationary instrument, with an observer, is placed at some point of known altitude that has been selected as the basis of operations. This instrument is observed regularly every fifteen or thirty minutes, and a careful record kept of such readings, as well as of the time and temperature corresponding to each.

Meanwhile, the engineer travels through the district he intends to survey, taking observations wherever he sees fit, and keeping a careful record of their location, time, temperature, etc. When he is through with his work, an observation at the point of known altitude is computed for each of his observations, from the record kept by the assistant; this having been done, the difference of altitude between each point of observation and the point of known altitude is obtained in a simple way, by means of the subjoined table No. 1, which has been taken from *Meteorological and Physical Tables of the Smithsonian Institution.* [Other convenient tables are given in *The Aneroid Barometer*, Van Nostrand, New York, 1888, and in the above mentioned publication of the Smithsonian Institution.]

For instance, suppose 29·5 to have been the reading at the point of known altitude, and 26·5 the reading taken by the engineer, both corrected to graduation, etc., and reduced to 32° F., and again, suppose 70° and 60° to have been the respective temperatures of the surrounding air, then we obtain from the table:

For 29·5 inches and 70° F., ...	96·5
For 26·5 inches and 60° F., ...	105·3
Mean, ...	100·9

This mean, multiplied by the difference of the two read-

ings expressed in tenths of an inch, renders the difference in altitude:

$$30 \times 100{\cdot}9 = 3{,}027 \text{ ft.}$$

The use of this table gives results of sufficient accuracy for all practical purposes, so that recourse to the complicated barometrical formula is not required.

Readings should always be taken in the same position of instrument, preferably the horizontal one.

TABLE No. 1.

HEIGHT IN FEET OF A COLUMN OF AIR CORRESPONDING TO ONE-TENTH OF AN INCH IN THE BAROMETER.

Barometer Reading in Inches.	Temperature of Air in Degrees Fahrenheit.					
	40°	50°	60°	70°	80°	90°
23·0	116·2	118·8	121·3	123·8	126·4	129·9
23·5	113·7	116·2	118·7	121·2	123·7	126·1
24·0	111·3	113·8	116·2	118·6	121·1	123·5
24·5	109·1	111·5	113·8	116·2	118·6	121·0
25·0	106·9	109·3	111·6	113·9	116·3	118·6
25·5	104·8	107·1	109·3	111·6	113·9	116·2
26·0	102·7	105·0	107·2	109·5	111·7	114·0
26·5	100·9	103·1	105·3	107·5	109·7	111·8
27·0	99·0	101·2	103·3	105·5	107·6	109·8
27·5	97·2	99·3	101·4	103·5	105·6	107·8
28·0	95·4	97·5	99·6	101·7	103·8	105·9
28·5	93·8	95·8	97·9	99·9	101·9	103·9
29·0	92·1	94·1	96·2	98·2	100·2	102·2
29·5	90·6	92·6	94·5	96·5	98·5	100·4
30·0	89·1	91·0	92·9	94·9	96·8	98·8
30·5	87·6	89·5	91·4	93·3	95·2	97·2

TABLE No. 2.

REDUCTION OF MERCURIAL COLUMN TO 32° F., BRASS SCALE TO BAROMETERS CORRECT AT 62° F.

Temperature.	Reading of Barometer.		
	30 inches.	25 inches.	20 inches.
32°	·009	·008	·006
35°	·017	·015	·012
40°	·031	·026	·021
45°	·044	·037	·030
50°	·058	·048	·038
55°	·071	·059	·047
60°	·084	·070	·056
65°	·098	·082	·065
70°	·111	·093	·074
75°	·125	·104	·083
80°	·138	·115	·092
85°	·151	·126	·101
90°	·164	·137	·110
95°	·178	·148	·118
100°	·191	·159	·127

The corrections contained in this table have to be *subtracted* from the reading of the mercurial barometer, in order to reduce the same to a temperature of 32° F.

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